Earth's Paleobiosphere

ES-6 The student will demonstrate an understanding of the dynamic relationship between Earth's conditions over geologic time and the diversity of its organisms.

Key Concepts for ES-6:
Planet conditions: hydrosphere, atmosphere, biosphere
Geologic time: geologic time scale – eons, eras, periods, epochs; complexity & diversity of life
Fossil evidence: types of fossils within various environments
Geologic dating methods: index fossils, relative dating, radiometric dating
Age of universe & Earth: cosmology

ES-6.1 Summarize the conditions of Earth that enable the planet to support life.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have studied throughout elementary grades the needs that plants and animals must have in order to survive and reproduce. In 6th grade students summarized characteristics that all organisms share, such as the obtainment and use of resources for energy, which they would get from the environment. In 7th grade students studied the biotic and abiotic environment of Earth and how organisms interacted and responded to the components of the environment. In Earth Science students will focus on Earth as the unique planet with the conditions that can support life.

It is essential for students to know that without Earth's hydrosphere, atmosphere, and environments of the biosphere, life could not exist on Earth.

- Earth is suitable for life because of its unique orbital position that allows for water to exist in all three phases on the surface. Water makes Earth unique. The *hydrosphere*, Earth's mass of liquid water that is constantly on the move, is vital to life within it and also to life on the land.
- Earth is surrounded by a life-giving gaseous envelope called the *atmosphere*. Earth's atmosphere provides the air that organisms need to breathe and also acts to protect organisms from the Sun's intense heat and radiation.
- The *biosphere* includes all life on Earth – life found from the depths of the ocean floor to life existing in the lower atmosphere. This biosphere contains the biotic and abiotic environments necessary for organisms to breathe, obtain/make food, find shelter, and reproduce. Organisms not only respond to the environmental conditions on Earth, but through interactions, they help maintain and alter the environment also.

Scientists examine evidence from the rock record and fossils to develop their theories about the existence of life and the changes in Earth's conditions. During the formation of these spheres of Earth, scientists have found evidence that life forms went through many changes in order to exist. Geologic changes, changes in the amount of Earth's surface water, changes in the atmosphere resulting in climatic changes and temperature changes have affected the life forms in existence throughout the history of Earth.

It is not essential for students to know evolutionary theory with this indicator; students are focusing on Earth conditions for survival, not natural selection and organism change over time.

Assessment Guidelines:
The objective of this indicator is to *summarize* the conditions on Earth that are necessary for the support of life; therefore, the primary focus of assessment should be to generalize major points about how Earth as a planet meets of the needs of living things.
In addition to *summarize* appropriate assessments may require students to:

- *infer* how the hydrosphere or atmosphere or biosphere gives Earth life-sustaining properties; or
- *identify* the spheres of Earth necessary for life on the planet.

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ES-6.2 Recall the divisions of the geologic time scale and illustrate the changes (in complexity and/or diversity) of organisms that have existed across these time units.

Taxonomy level: 1.2-A Remember Factual Knowledge
2.2-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to the geologic time scale and the vast diversity of life that it presents in 8th grade. Earth Science will further develop this concept.

It is essential for students to know that scientists have developed a geologic history of Earth from evidence found in the rock layers.

- The type of rock that makes up the layer and the fossils that are found in each layer help to reveal information about the conditions that existed when the layer formed.
- Fossils also indicate the kinds of organisms that lived during that geologic time.
- Students need to know the major divisions, *eons* and *eras*, and the fact that *periods* within the eras were further divided based on the life-forms that were abundant or became extinct during the time those rocks were deposited.
- A further division during the Cenozoic Era is *epochs*. Since the rock record during this last era is relatively complete with less time for change due to weathering and erosion, different groups of organisms can be used to distinguish the various epochs.

Students should study various illustrations of the geologic time scale noting major geologic events taking place on Earth. They should use the information on the illustrations to note changes in life forms both in the complexity of the organisms (e.g. simple marine invertebrates to plant life to vertebrate amphibians and reptiles to flowering plants to mammals) and the diversity of those life-forms through time.

It is not essential for students to memorize the names of the periods and epochs on the geologic time scale – the order of the major eras is important. Students should not have to identify life forms in existence during various periods or epochs unless a geologic time scale illustration is available for interpretation.

Assessment Guidelines:

The first objective of this indicator is to *recall* the divisions of the geologic time scale; therefore, the primary focus of assessment should be to retrieve relevant knowledge about how this scale is divided from long-term memory.

Another objective of this indicator is to *illustrate* the changes in life forms on Earth over geologic time; therefore, the primary focus of assessment should be to find or use illustrations of the geologic time scale to show how life forms have changed in complexity and diversity over time.

In addition to *recall* and *illustrate* appropriate assessments may require students to:

- *classify by sequencing* the order of the eras on the geologic time scale; or
- *summarize* major changes that occurred in life forms over geologic time.

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ES-6.3 Summarize how fossil evidence reflects the changes in environmental conditions on Earth over time.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to fossils, and some of the types of fossils, in 3rd grade; they also studied how fossils could give scientists ideas about early environments. In 8th grade students summarized how scientists used many types of fossils to study Earth's diverse life forms and changing environments. In Earth Science students will develop this concept further as they study evidence from fossil populations of organisms that indicate changes in their environment.

It is essential for students to know that there are various types of fossils.
- Some may be direct evidence of the organism such as shells, bones, or plant fragments.
- Others may be indirect evidence, such as tracks, trails, or footprints.

(Students may review the various types of fossils from their previous learning.)
- A fossil is considered to be *originally preserved* when the organism remains as it was when it died;
- A fossil is considered to be an *altered* fossil when all of the organic material has decomposed and been replaced by minerals deposits.

Fossils of all types furnish scientists with clues to changes that have occurred in Earth's past history, such as changes in climate and environment.
- If a fossil of a warm climate reptile is found in a northern colder region today, the fossil indicates that that area once had a tropical climate.
- Tropical plants have been found in Antarctica; fossils of marine animals have been found far from any ocean.
- Students should be researching examples of fossil organisms that give scientists these clues.

The study of fossils allows scientists to
- describe how organisms have changed through time;
- have evidence of ancient environmental conditions;
- find patterns and cycles that can be used to predict future phenomena, such as climactic changes;
- locate energy resources based on the environmental conditions needed for fossil fuels to have formed.

It is not essential for students to know how each fossil type was formed, unless this is in context of review. This indicator is not a complete study of the environmental conditions on Earth over time.

Assessment Guidelines:
The objective of this indicator is to *summarize* how fossil evidence reflects changes in environmental conditions on Earth; therefore, the primary focus of assessment should be to generalize major points what fossils can reveal about these changes.
In addition to *summarize* appropriate assessments may require students to:
- *recall* different types of fossils;
- *exemplify* fossils that could be found in various environments; or
- *infer* a type of environment based on fossil evidence.

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ES-6.4 Match dating methods (including index fossils, ordering of rock layers, and radiometric dating) with the most appropriate application for estimating geologic time.
Taxonomy level: 2.6-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade were introduced to index fossils and to determining the relative age of rocks through the ordering of rock layers. Students have not studied radiometric dating before this indicator in Earth Science.

It is essential for students to know that rocks contain clues to Earth's past, including life forms and evidence of geologic change. Several ways to learn about and date Earth's past come from the type of rock found, the rock layers, and fossils found within some of the rocks. Methods of dating the Earth are determined by whether the need is for which came first and sequencing to later dates, or whether the need is for an actual age.

Relative Age Dating: (used if the need is for ordering oldest to youngest in geologic time)
Ordering Rock Layers
The geologic principles of *uniformitarianism, superposition,* and *cross-cutting relationships* help scientists to determine the ordering of rock layers and the changes that occur to those rock layers over time. Weathering and erosion can disturb the rock layering, and an intrusion or a fault can indicate younger or more recent changes to the rock layer(s) in which they are found.

Index Fossils: (used to aid in the ordering of rock layers or to age the rock layer)
Geologists use index fossils to correlate rock layers over large geographic areas and to date a particular rock layer.

- An *index fossil* must be easily recognized, have been abundant and widely distributed geographically. It also must have lived during a short period of time.
- With this information, a scientist can use index fossils to date the age of the rock layer based upon when that organism was known to have lived in geologic time.
- An index fossil found in rock layers in different areas of the world indicates that the rock layers were probably formed during the same period.

Radiometric/Absolute Age Dating: (used if the need is for knowing the actual age of a rock or fossil)
In order for scientists to determine the actual age, or *absolute age*, of a rock layer, radioactive isotopes of elements found in rocks or fossils are used.

- *Radioactive isotopes* give off energy and particles at a regular rate, not influenced by environment, temperature, or any other changes, and eventually change to other isotopes of that element or into an isotope of a different element. They function as a natural clock. This process is called *radioactive decay*.
- By knowing how long a radioactive element takes to decay into its "daughter" elements, and by determining the ratio of the original radioactive element still present compared to the amount of "daughter" element, the age of the rock being analyzed can be determined. Since this process takes a long period of time for most radioactive elements, geologist use the length of time its takes for one-half of the original amount to decay, called the *half-life*, to determine age. Students should know why uranium-238 may be used for one dating compared to carbon-14 in another instance.

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It is not essential for students to know the details of the particles given off or the various daughter elements that occur in the radioactive decay process; only a general understanding of radioactive decay is essential.

Assessment Guidelines:

The objective of this indicator is to *match* methods of dating rocks and fossils with appropriate need for the dating, therefore, the primary focus of assessment should be to determine from the need indicated whether relative dating, index fossils, or absolute/radiometric dating would be the best method to use.

In addition to match appropriate assessments may require students to:

- *summarize* the major points about each type of dating method;
- *compare* relative and absolute dating;
- *infer* the age of a rock through the use of half-life; or
- *recall* the geologic principles involved in relative dating.

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ES-6.5 Infer explanations concerning the age of the universe and the age of Earth on the basis of scientific evidence.
Taxonomy level: 2.5-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concept in this indicator in any previous grade.

It is essential for students to know that
- Scientists collect data using various types of telescopes and instruments to detect changes that are going on out in the universe.
  - This study, called *cosmology*, not only studies the universe as it is, but also forms models and theories concerning it origin and age.
  - Students should study the scientific evidence and use that evidence to make inferred explanations about the age of the universe.
- Scientists are collecting and analyzing data that are used to develop theories about the age of Earth.
  - Radiometric dating has determined the age of the oldest rocks on Earth at present time but the rocks that form Earth's crust have been eroded over time.
  - Meteorites and moon rocks have also been studied for evidence of age.
  - Students should study the scientific evidence and use that evidence to make inferred explanations about the age of Earth.

It is not essential for students to know the details and mathematics (e.g. use of the Hubble constant) of all the scientific evidence; but a general understanding of what scientists have discovered, used, and analyzed in order to come up with a determination of the age of the universe and Earth is appropriate.

Assessment Guidelines:
The objective of this indicator is to *infer* the age of the universe and Earth; therefore, the primary focus of assessment should be to draw scientifically based conclusions/explanations based on evidence gathered by scientists.
In addition to infer appropriate assessments may require students to:
- *summarize* methods that scientists use to gather information from across the universe or from on Earth to determine age;
- *recall* the purpose of the field of science called cosmology; or
- *identify* the age of the universe and the Earth as determined by scientists.